AC 2008-1109: RISK MANAGEMENT – ARE ENGINEERS THE PROBLEM OR THE SOLUTION?

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Risk management – are engineers the problem or the solution?

Abstract

The introduction of new technology exposes projects to many risks. Engineers are the strongest advocates for technology change but since risk and novelty are inextricably linked, that means that engineers are also often the greatest contributors to project risk. The conventional procedures for risk identification and control can be tedious and often trigger remedial action too late. This paper presents an alternative approach that is based on the outcomes of many dialogs with senior engineers in a series of industry short courses. It treats risk as the main source of variation in project metrics and advocates a template to systematically expose the sources, especially risks that are associated with every decision. The techniques of quality control are then used to parameterize and prioritize the risks so they can be proactively managed within a technology project.

Risk – the engineering challenge

The impact of new technology on products as well as the tools to design and sustain them is a familiar feature of engineering today. There have also been substantial changes in the way that high-tech business is carried out. Globalization and outsourcing are familiar terms in their economic context but they have also changed the way in which engineering jobs are structured. We can view current business operations in two categories – steady state and dynamic as shown in figure 1.

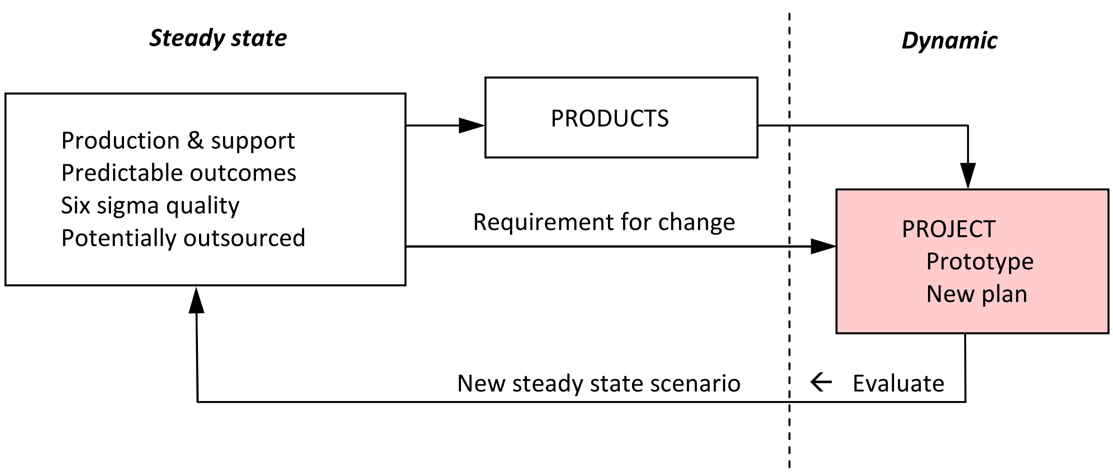

Figure 1. Process to manage change

The requirements for change come from the need for improved products or ways to implement new technology to deliver them. In either case, the process to define and evaluate exactly what has to be changed is invariably organized as a project. Projects should be like children's stories. They have a beginning, middle and end and have simple, clear content. At least, that's the intent. Since projects determine the time it takes for a company to have a presence in a new market, success is vital, especially in the fast-changing high-tech business sectors. Technical programs therefore go to great lengths to make sure that they employ rigorous project management techniques. It reassures customers and company executives that the project will meet its primary metrics for performance, cost and schedule.

The partition represented in figure 1 is itself the outcome from changes in technical capabilities. Over the past thirty years, the variation associated with manufacturing and the associated business support operations has been reduced to the point where results are demonstrably controlled and predictable. Perhaps the most publicized example is Intel's "Copy exactly" strategy [1]. It has paid off in terms of yield and rapid introduction of new technology. It points to another way to define project success - when the results meet the criteria for steady state operations.

To assist the project management process, there are software tools, performance measures and increasingly complex dashboard representations of status. Yet most projects still manage to miss their goals – invariably on the wrong side – and plans are obsolete almost as soon as they are published. This is not a new phenomenon. Over the past two decades, it has been the subject of much study and even more analysis, yet still Cobb's paradox [2] prevails: *"We know why projects fail, we know how to prevent their failure - so why do they still fail?"* One of the reasons may be that we are managing the wrong things. The challenge to minimize deviations is represented in figure 2.

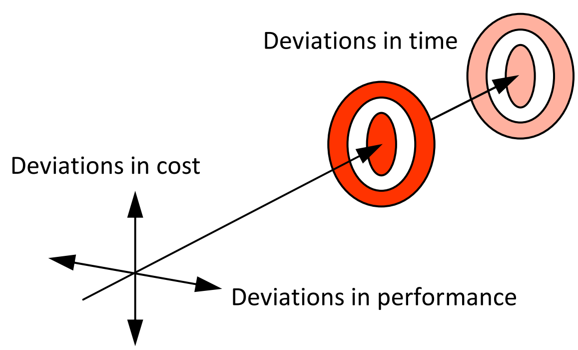

Figure 2. Challenge to reduce deviations.

If we define risk as anything that can change the plan of record, then risk management becomes the key activity in steering a project to its desired goals. By using projects to develop the path for technical change, the associated risks that can be attributed to engineering effects are enhanced. We can therefore point to engineers as the biggest contributors to project risk. However, if the goal is to eliminate the factors that cause the variations in figure 2, then engineers also have the solutions. Minimizing variation has echoes of SPC for manufacturing control. This is a link that will be developed later in the paper. However, any glance at the contents of a bookshop or a project training program shows that much greater emphasis is given to project planning than to the management of risk. Even the Project Management Body of Knowledge [3] devotes only 10 % of its content to risk management so the subject is due for some constructive enlargement.

A subsidiary issue exists for projects that deal with development of new technology. Most project management literature and training is very general and reflects the experience of generations past. As a result, the issues of outsourcing and global operations with fast-changing technologies have yet to receive the attention their current role demands.

Methodology to analyze technical risk management

The topics covered in this paper are the outcomes of a three-year iterative development of industry-based short training courses. Sixteen courses have been delivered to participants from the five major companies who are members of the Arizona JACMET consortium. Over 200 participants have been involved. Most held senior-level positions. They have been project managers or candidate chief engineers but there have also been enough with supply chain interests to demonstrate that the activities of these individuals are also an important component of the solution.

Course scope and content is reviewed by a team of experienced industry professionals who set the overall requirements and expectations. Since risk overlaps the domains of chief engineers and project managers, this course has oversight from two committees. They comment on the participant feedback from every course and make or accept recommendations for change and interactions with other courses.

The starting point is to admit that risk management is complex. A good representation using a mind-map format [4] is given in figure 3.

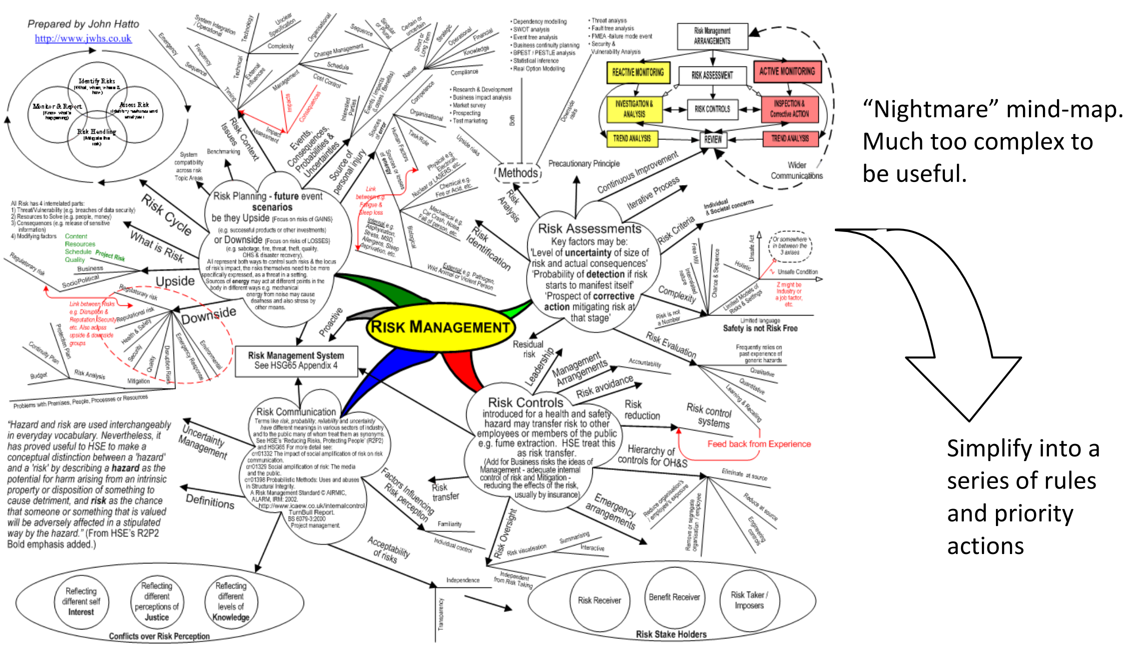

Figure 3. Representation of risk management

A large-font print-out of figure 3 confirms that most of the features are to be expected in any representation of project risk. However, the layout of the topics and the tangled juxtapositions helps to emphasize how varied and interactive the issues are. No teaching process can work with such a jumble of concepts. A much simpler and more logical set of relationships had to be developed.

The objectives for the risk management course were simple:

1. Demonstrate that risk is a component of all decisions.
2. Map the diverse forms of risk.
3. Show how prudent practice is developed.
4. Provide examples to hone skills and confidence.
5. Point to techniques for further development.

The first objective is the unique feature of the approach and represents the strong engineering background of the JACMET consortium and course participants. No technical decision is absolutely clear and in a large project there are many thousands of interacting decisions. Combinations of apparently independent decisions can easily lead to unacceptable risks even when each decision can stand on its own. This observation led to the course mantra, *"Risk is the dark side of every decision"*. The take-away point is that all decisions have to be conditioned by appraisal of the risks involved. Risk assessment afterwards is too late.

Sources of risk

The conventional view [2] is that 80 % of projects miss their targets for six reasons:

1. User involvement
2. Executive management support
3. Clear requirements
4. Proper planning
5. Realistic expectations
6. Smaller project milestones

For the business we are addressing, considerable effort – but perhaps not enough – is devoted to eliminate deficiencies in the first five. However, # 1 is ambiguous. Too much user involvement can also lead to changes in the plan and therefore risks. That issue along with # 6 will be addressed later.

The simplest explanation for Cobb's paradox is that we do not adequately absorb the lessons learned from past projects. However, that simple explanation is not so easy to remedy. New projects usually have a core of participants who have worked together before and it is all too easy for 'groupthink' to predominate and everyone assumes the common knowledge. Second, figure 1 shows that projects are about change. Some (or even most) of the operational conditions are new so past experience has to be recognized to be of limited utility and therefore modified to meet the needs of the new project. It is significant that the most successful project leaders devote time at the very beginning of each new project to filter the team experience to match the new case and to identify gaps in know-how or information.

The tempting approach to risk identification is to have a brainstorming session. That can work well, especially if many of the participants have not worked together before. However, it is a 'burst-mode' technique that does not offer enough sustained study to uncover the risks in complex technical systems. To follow the initial brainstorming, a practice at which engineering leaders excel [5] has been introduced. It is the capability to break complex issues into many strands and at the same time to understand the many interactions between these strands. The evidence can be seen in all engineering design, analysis or program management. However, the process is too often taken for granted or even dismissed as an obsession with detail. This is the real paradox in risk management. Somewhere in that detail lies the seed of the issue that will derail the project. However, there is no time to examine every issue in detail and everyone has to recognize that too much paranoia introduces other problems.

The goal is therefore to set up a process that will systematically cover all the likely sources of risk and then complement it with a continuous review process that will identify the most serious risks and link them to trigger points for action.

One of the advantages of developing good-practice methodologies through short courses is that each delivery can be considered as an experiment. A formulation is developed and tried against the experience of about a dozen senior engineers. It fits – but not quite – and the resultant discussion highlights some required content changes. The changes are implemented in the next iteration and so on. In some cases the outcomes traversed a full circle but in general, the process has become steadily more refined and robust. Ten major categories of risk sources have been identified:

1. *Estimates*. At the beginning of a project, there is often little hard information so estimates are widely used. However, it needs a disciplined process to tag estimates for what they are and to revisit them systematically and substitute hard data or at least have a timescale for doing that. The risk is that with the passage of time, estimates are perceived as facts.
2. *People*. The usual problem is that there are not enough people with the right competencies at the appropriate time in the project. We should also acknowledge the more subtle issues that may be reflected in the different generations or international background of the project team.
3. *Design.* This should be straightforward with appropriate simulations and trade studies to support the outcomes. However, the consequences of wrong estimates and inexperienced people can quickly lead to many latent design risks.
4. *Technology.* Change is an assumed feature in technology, especially for electronic functions. It is particularly important for its impact on the long term evolution of systems. Fortunately, new electronics technology is usually smaller, more powerful, more reliable and cheaper than its predecessor. Of course, the

planned benefits may not accrue if the technology takes longer than expected to move to the desired readiness level [6].

5. *Internal factors*. The project process inherently optimizes results for each project. Unless there is very strong executive management and accountability, projects can easily diverge and the synergy of being one organization is lost. It doesn't matter until a competitor demonstrates the alternative.
6. *Suppliers*. One consequence of having highly capable steady-state operations (figure 1) is that it is cost-effective to outsource many of the functions. As the process has been extended to cover global supply, new categories of cultural and trade risks have been introduced.
7. *Customer*s. As the outsourcing process progresses, in-house customers are increasingly replaced by groups in different companies. That leads to a more formal information exchange process and an equally formal conflict resolution process. Both absorb time and effort - especially from senior staff – that is almost never anticipated in the project planning phase.
8. *Intrinsic.* Every organization faces categories of risk by virtue of the features of its business. Large cash-rich companies have the deep pockets that attract lawsuits. Doing business with the Government has its own idiosyncrasies. The consumer market is fickle and subject to rapid change but the rewards can be large. However, even success brings the risk of raised expectations.
9. *External.* Everything above the project level falls into this catch-all category. It can range from a company re-organization to an earthquake. The qualification is that the project participants can do nothing to prevent the event but they do have to have a contingency plan to react if the event is at all likely.
10. *Timing.* Too early means having to find lots of new solutions. Too late means trying to catch up; rarely a successful activity. Timing of decisions and risk are inseparable.

The list is intended to be comprehensive enough to provide an easy starting point for discussion and further sub-division. Within the short-course activity, a class could examine a new but topical technical issue and within 30 – 40 minutes, provide a very passable risk profile. Even if a risk is later given a low importance, the advantage of this process is that the risk is given visibility. Any risk considered, no matter how briefly, has a better chance of being subjected to mitigating action before it becomes serious.

One final feature of the source list is that it does vary substantially throughout the life cycle of a product. At the concept phase, it is difficult to argue that substantial effort should be devoted to risks that may only be associated with end-of-life (EOL) of the product. However, the comments above on risk visibility apply. Even if it is only recognized that some aspects of EOL will eventually have to be considered, then the most obvious pitfalls will be avoided and some provision will be made for future review. In all cases, the outcome from the analysis of sources is a long list of potential risks. Now the process has to be ordered to identify and manage the most serious.

Risk parameters

Risk reduction is an intrinsic factor in the system design process. Trade studies are used to find the high level balance between performance and risk. At a more detailed technical level, simulation can often be extended to provide a full 'Design of Experiments' review of sensitivity to major variables. During the design process, risks can be managed in a number of ways:

- Elimination of the risk by using a different design
- Avoidance by working in a different region of the design space
- Transfer of risk to another area, eg, by buying a pre-tested assembly
- Using an alternative solution that carries known lower risks
- Reducing risk by increasing design safety margins or better materials.

At the end of the design stage, these choices relating to risk mitigation should have been thoroughly considered and a selection made. Whatever risk remains then has to be accepted. Even given a thorough review process, the resulting list of risks is never complete or sufficiently accurate. The list can be viewed by anyone of uncharitable disposition as an embarrassing statement of the negative capabilities of the project team. The recommended solution is the same process that is used to manage all variables in a product – identify a list of qualifying parameters, prioritize their impact, measure often enough to detect change and set control limits for acceptability.

There are two starting points to evaluate the parameters of any specified risk. The development steps are shown in figure 4.

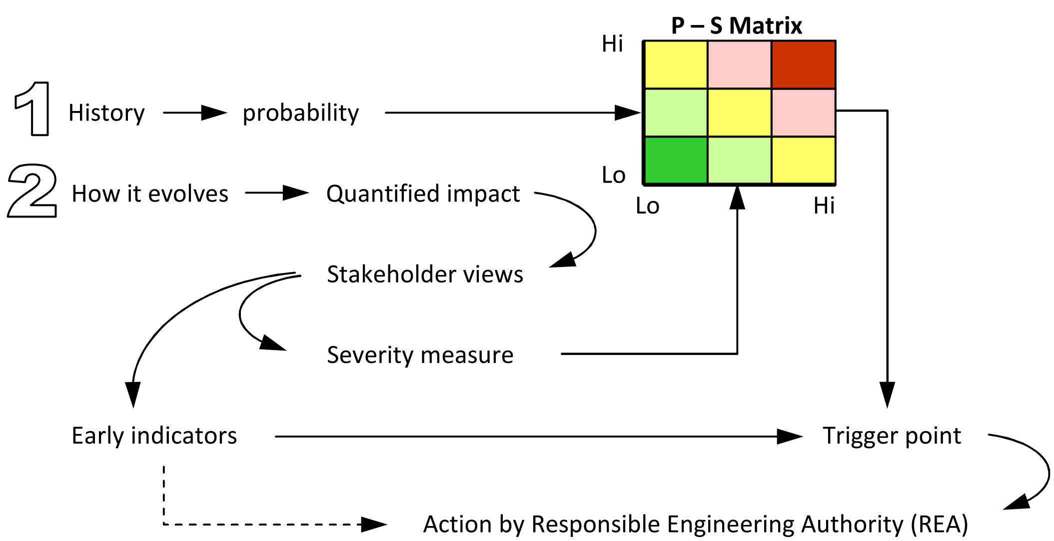

Figure 4. Sequence to manage risk parameters

The two paths lead to the conventional probability-severity matrix representation. By following the steps shown (with as much additional sub-division as possible), the matrix can be better than simple guesswork and when the inevitable challenges are leveled at the ‘red boxes’ in the P - S matrix, a reasoned and quantitative explanation can be given. The end-point is to ensure that every risk has a fully documented parameter set and that there is a named individual - the risk owner - who is accountable for the information and validating its accuracy at regular intervals.

Consideration of all stakeholder views in path 2 is intended to avoid disagreements later when a risk has become a problem and everyone has the benefit of perfect hindsight. If the early indicators that lead to the trigger point for action are clearly identified in advance, there is a correspondingly greater chance that they will be reported to the risk owner. This section of the course is called ‘Group Survival 101’.

When the impact of any risk is quantified, it is important to consider all aspects and potential penalties. The project manager will ensure that the factors relating to project scope, budget, schedule and performance are fully analyzed. However, it is usually less clear who is accountable for impact beyond the project. Non-delivery of even a modest component can have ripples from a project into a program and even beyond that into a strategic capability. If the press gets involved, it takes on the features of a crisis and help from headquarters follows. The process shown in figure 4 goes a long way towards defusing the wider impact of risk events.

Outcomes for industry participants

During the short courses, one of the main outcomes from case study reviews was that the risk management process was too modest and too late. As a result, many issues had to be remedied at a point where the results were serious and large projects were visibly affected. That in turn demanded the attentions of senior engineers for urgent troubleshooting and fire-fighting. The apologists would say that the start-up period for any project is a hectic time and there is never enough available resource to manage all the short-term demands. Anything without a close deadline is therefore postponed. For those with long memories, this is very similar to attitudes that were expressed about manufacturing quality 20 – 30 years ago. At that time, quality remained embarrassingly low until techniques such as TQM and Six Sigma were adopted. The analogy between risk management for projects and quality control in manufacturing is very constructive. Since the quality control process is well-known and accepted, the analogy makes it easier to argue for similar concepts and techniques to be used to generate a process to reduce variation in projects. It may seem strange to have to argue like this to give risk management processes more emphasis but Cobb’s paradox is a persistent malaise that needs creative solutions.

The first step was to create a template to define the evaluation process. The goal is to have enough data to show project performance variation at its early stages and before it becomes critical. The analogy is a trend line on a control chart. This implies having a lot more data on risks than is normally collected. However, the process outlined above (to systematically examine the ten sources of risk in their project context) provides that level of data. Ideally it should be linked to the regular reporting metrics for project progress. If that can be done, the marginal cost to collect enough risk data is very low. A simplified version of the process is shown in figure 5.

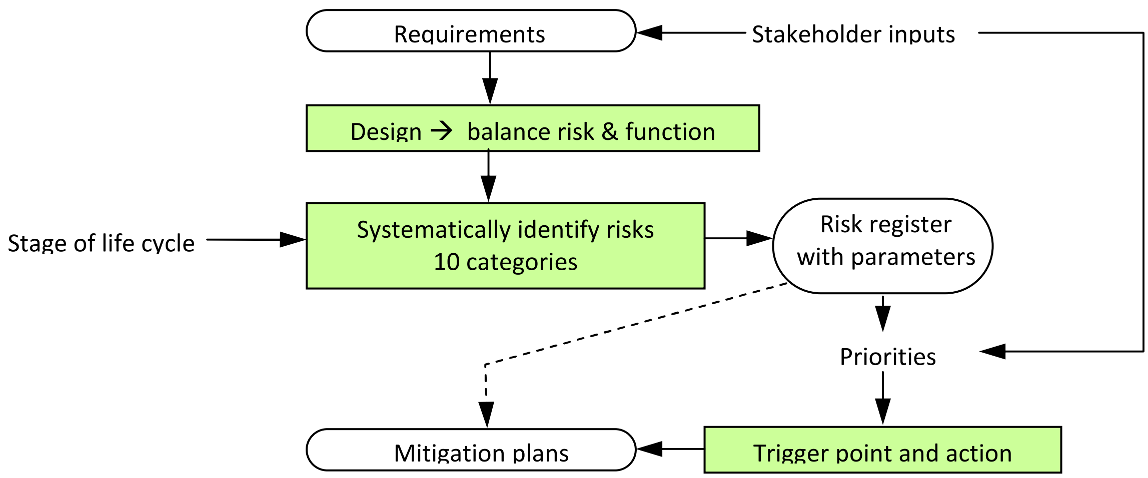

Figure 5. Risk management template

Unlike most existing risk management practice, it is not a one-time compilation done at the same time as the project plan. It is a continuous review process that is used in the same way that control limits are applied in production. In this case, the raw data on new and updated risk comes from decisions. Decisions are being made continuously. Every decision contributes to risk. When risks are made visible, they are better managed. This process can be implemented long before a risk transmutes into a problem.

The latest versions of the course have been adapted to address many interests. The first day is presented to a mixed group of project managers, chief engineers and supply chain managers. It deals with the factors demonstrated in figures 4 and 5. The second day of the course has three versions, each with different emphasis and examples to suit the specialist interests.

One unexpected outcome emerged from the cross-functional sessions. Risk management conventionally only represents risk probability and severity. Engineers use a very similar representation for failure modes and effects analysis (FMEA). However, there is an important difference. The FMEA process adds a third measure: the probability that the detection systems in place will detect the failure (risk) at the intended point. This is a useful measure that can be added to any project risk evaluation process for almost zero effort. Project managers and Failure Engineers have been on two parallel tracks and no-one knows why the two processes have not borrowed more from each other. That has changed now.

A second outcome also deserves more visibility. The process to identify risks through continuous sub-division across many categories is analogous to the process used to define project tasks and it delivers the same benefits. The more an activity can be divided up into sub-tasks, the more it is understood. If it is understood, then it can be carried out reliably and predictably. Both of these attributes imply lower risk. The complementary case is also valid. The more the causes of uncertainty can be isolated, the more they can be contained in terms of their contribution to project risk.

Applications to academic projects

Although the activities covered in this paper have derived exclusively from dialogs with industry-based participants, there are some useful outcomes for academic projects. However, we should first recognize four important differences. Student academic projects (at least up to PhD level) are usually:

1. Undertaken by individuals or a small group. The participants do not have much variety or depth in the experience they bring to the project.
2. Short in duration. Even a capstone project is only equivalent to about a month of full-time energetic project work. That's not long to learn practical techniques.
3. Not part of a continuous development scheme where one project depends on the timely delivery of results from another.
4. Learning-focused. That means that although a project may be funded by a contract, student outcomes should not be on the critical path for deliverables.
5. Paced by what the students do not know and have to learn by practice. That's the point of doing a project but it makes it very difficult to introduce much rigor into the project management or risk assessment process if no-one knows how long a task will take or what its outcome will be.

For an injudiciously selected project, these topics can be show-stoppers. The role of the faculty advisor is vital to make sure that there is enough repetition for students to learn to calibrate their own capacity and then how to plan to use it effectively.

Academic projects can also benefit from the continuous sub-division of project activities into ever-smaller tasks. Most students initially only consider technical risks that arise from their own lack of familiarity with the tools or techniques. The risk template can help the systematic breakdown by demonstrating the wide range of factors that limit performance. Delays in delivery of components or a computer crash can have equally dramatic effects on progress and students find it reassuring to know that they are not always the biggest contributors to chaos. The sub-division of risk factors has to be taken to the point where students can see what they know (and therefore should be able to deliver) and what they have to learn. That is usually when the light bulb switches on and they start to manage the project for themselves. At that point, all academic risk factors fall abruptly and permanently.

Acknowledgements

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